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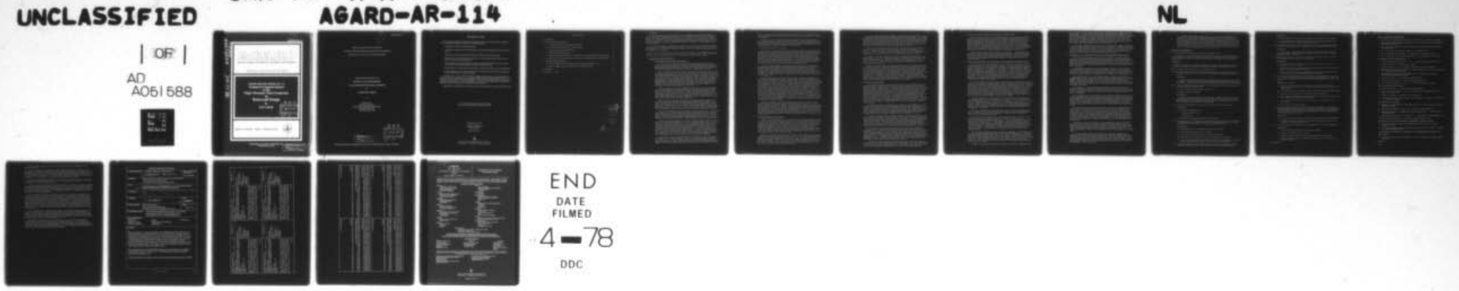

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AGARD ADVISORY REPORT No. 114

Technical Evaluation Report on the Flight Mechanics Panel Symposium on Rotorcraft Design

by

H.R.Velkoff

NORTH ATLANTIC TREATY ORGANIZATION

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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.114

TECHNICAL EVALUATION REPORT

on the FLIGHT MECHANICS PANEL SYMPOSIUM

on

ROTORCRAFT DESIGN

by

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This Advisory Report was prepared at the request of the Flight Mechanics Panel of AGARD.

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1.0 Introduction

A three day symposium on Rotorcraft Design was held at the NASA Ames Research Center, Moffett Field, California from the 16th through the 19th of May, 1977. The AGARD Flight Mechanics Panel arranged the meeting. The program committee consisted of Mr. E. S. Carter (U.S.A.), Dr. S. R. M. Sinclair (Canada), and Dr. Ing. P. Hamel (FRG). The goal of the symposium was three-fold, to review the status of rotorcraft design and development, to consider the possible divergence of the development pattern of military and civil helicopters, and to explore the possibilities for greater coordination in the development of future rotary wing aircraft.

To achieve these purposes the symposium was arranged in five sessions in which the authors presented formal papers which are referenced at the end of this TER. A sixth and concluding session consisted of a panel discussion of critical points raised during the meeting and of the question of coordination between the military and civil agencies.

This report will first present an overview of the entire conference, then the recommendations will be presented. Details on any specific subject may be found in the individual papers. Numbers that appear at the end of sentences in the report refer to the individual papers listed in the references.

2.0 Review of the Technical Discussions

2.1 Military Requirements and New Military Rotorcraft

Helicopters now being introduced into military use are greatly advanced over those introduced a decade ago. Present helicopters meet stringent requirements arising from well defined threats and operational needs. They have evolved from general purpose machines to highly sophisticated aircraft having specialized roles. Attack helicopters, scout helicopters and "utility" helicopters with high rates of climb are not expectations, but reality.

This increasing specialization can be seen in the definitive requirements that the armies and navies of the NATO countries have evolved. Land-based forces ask for helicopters that can withstand battle damage and continue to perform their mission. They must be able to hover at altitude on hot days and carry the full mission load. Agility, the ability to maneuver and fly in close proximity to the earth, perform pop-up and lateral jinking maneuvers, appears as a paramount need. Attack helicopters must be capable of carrying an array of weapons and sensors combined with low detectability and vulnerability. The aircraft must be crashworthy. Maintainability and reliability must achieve high standards and on-board fault diagnostic capability and on-condition replacement can be anticipated. (1-6) Also significant is the recognition by military planners that flight in poor visibility, night, and under icing conditions will be vital in the combat use of helicopters. (1)

If one now examines the use of the helicopter by naval forces or on long overseas duty, one can find some significant differences from the aircraft specifically tailored to meet ground force requirements. Missions at sea may require extended flight duration, minimum reaction times, and long periods of hovering. Where the ground forces might specify air transportability and the ability to live in the field under primitive conditions, the navies ask for carrier compatibility. Where air transportability and low silhouette may call for squat minimum volume aircraft, the carrier compatibility asks for sturdy landing gear, blade folding and tail folding with restricted fuselage size.

Most of the aircraft designed to meet these military requirements were started with a clean sheet of paper, however some existing smaller helicopters have been adapted to meet specific military needs. (4,5,10,11) These aircraft tailored to meet the special requirements of the military; however, result in machines that cannot be adapted directly to civil operations. Requirements for low vulnerability, carrier compatibility, and low silhouette have no counterpart in civil operations. The added cost, weight, and small fuselage volumes resulting from military needs all act to limit the civil utility of helicopters so derived.

Some of the new helicopters offer new features of great potential ability. The hingeless rotors, flapping rotors without lubricated bearings, and teetering rotors with a centering spring tend to provide the control power and responsiveness necessary to meet the need for agility. These helicopters provide greater stability and ease of flying just at the time the demands on the pilot are becoming greater. These demands result from flight in nap of the earth and terrain following flight under all weather conditions and severe combat operation.

Though these operational demands are great the helicopter has shown itself to be immensely effective. In direct test against tanks in realistic simulated combat, the kill ratio of tanks killed per helicopter lost was 18 to 1. (5) The simulated combat revealed that ground observers were more effective than radar in detecting helicopters flying below or in the ground mask. The tests revealed that a properly maneuvering helicopter can evade ground launched IR seeker missles at distances beyond 1200 meters. It was also found that it was difficult for radar to lock-on the low flying helicopter. A typical average detection rate was 25% and lock-on success was about half that value. (5) Hostile aircraft were found to pose a lesser threat than IR missles or radar controlled anticraft guns such as the Quad-23. Thus, though the piloting of the helicopter in the nap of the earth is demanding, the test data have shown the aircraft to be quite effective in simulated combat conditions.

Looking ahead, concern was also expressed over the possibility of air-to-air combat with helicopters. (4) It is quite apparent in view of the test results reported in reference 5, that armed helicopters could be a formidable threat to other similarly armed helicopters. Questions immediately arise which impact aircraft designers and the research and development community. In air-to-air combat with helicopters near the ground, the demands on the aircraft,

the pilot, the sensors, and the weapons become more exacting, for, once engaged, a slower attack helicopter cannot run away and must either have superior agility, pilot skill, weaponry or survivability.

Looking at the entire spectrum of military helicopters from a small squad aircraft to heavy lift flying cranes, it seems apparent that little effort is being expended on the very small and very large size helicopters. At the moment funds to develop such aircraft are not available and present development efforts have been concentrated in the midrange of four place through medium lift aircraft of the UTTAS or Puma type aircraft.

2.2 Civil Operations and New Civil Helicopters

Any study of civil helicopter operations and technology reveals a split in the aircraft capability that is available to the civil user. On one hand extremely vigorous programs are underway to develop small and medium sized aircraft which use the very latest materials and technology. On the other hand, airlines are unable to purchase large helicopters for civil use even though these helicopters have been flying for years. Considering the smaller helicopters we can see the pioneering "hingeless" rotor with fiberglass blades of the MBB BO-105 which has been introduced widely into service. This has been followed by the advanced technology of the Aerospatiale AS-350, the Sikorsky S-76, and the Bell 222, and the Augusta 109. A combination of experience, new materials, and an extensive technological base has been applied to design these aircraft for specialized commercial markets.

The need for larger commercial helicopters has arisen because of the very successful experience with scheduled passenger service by BEA and KLM. BEA has used the largest civil helicopter available, the S-61N, in both scheduled passenger service and in support of offshore drilling. BEA made money with the helicopter in scheduled passenger service. In the south of the United Kingdom, when flying between the Isles of Scilly and Penzance, the helicopter has become the travel mode of choice over an alternative STOL aircraft and is quite successful as a commercial aircraft. (7) KLM has also used helicopters very successfully in oil well support. (9)

Based upon their success to date and projected needs, the airlines indicated that they would like a larger commercial helicopter. One that could carry about 100 passengers for about 250 miles at speeds over 200 knots would be desirable. The airlines indicated that they could utilize aircraft of the CH-47 or CH-53 types if they were modified and certified to meet civil requirements. These aircraft are not available to these civil operators even though the aircraft have been flying for many years in military service with fine operational records. The dicotomy is clear. On one hand the very latest technology is being made available to civil users of small rotorcraft, yet on the other hand the civil transport customer for large aircraft cannot even purchase technology that is of the order of 15 years old. Lack of certification keeps these helicopters from being available and is directly related to the high cost of certification. The financial risk to the manufacturers is high and the limited market potential makes the payoff uncertain to the extent that neither manufacturer has seen fit to initiate certification programs. In addition to certification cost, added costs are necessitated by the need to modify military aircraft for civil use. The fuselages developed for military use are generally inadequate to fully utilize the inherent performance capability under less demanding flight conditions. This disparity is significant in the CH-47 and CH-53 and extreme in the case of the UTTAS.

Although the commercial airlines expressed serious concern over the lack of certified large helicopters and the lack of utility of the newest military helicopters in a civil market, the makers of smaller helicopters indicate that successful exploitation of helicopters in both military and civil use is possible. In these sizes of helicopters, the manufacturers did not feel that there were any over-riding constraints which would prevent these helicopters from performing civil or military functions with modifications. (10,11) They pointed out that the MBB BO-105 and the Hughes 500 have had substantial military and commercial production, as have other helicopters in the past; the Alouette and the Jet Ranger. The 105 and the 500 appear to be undergoing new cycles of modification to adapt them to both new military as well as civil roles.

2.3 Rotary Wing Aircraft Research Vehicles

Several promising new concepts in rotary wing aircraft are presently undergoing exploration. The tilt rotor XV-15 has entered flight status. It has been hovered and flown in the helicopter mode at low speeds. The anticipated potential of the XV-15 tilt rotor aircraft reflected the optimism all new programs generate. (16) The design trade off made to achieve both good hover and good cruise in tilt rotor aircraft come at the expense of some added complexity and weight over a pure helicopter. None the less the potential gains in productivity appear very attractive if they can be realized. It is most encouraging to see in the XV-15 another of the new class of aerodynamically clean rotary wing aircraft. After these initial low speed tests the XV-15 will enter the NASA Ames 40 by 80 foot wind tunnel for further tests prior to full release for flight.

Extensive tests with the ABC helicopter have revealed that the coaxial rotor can achieve a high rotor figure of Merit approaching a value of $M = 0.8$. (17) Control difficulties which resulted in a very hard landing during initial flights at low speed have been corrected and flights have been made to speeds over 160 knots level flight. Load factors over 2.5g at 150 knots have been achieved. These tests indicate that the advancing blades actually do carry the load with increasing speed. In the next phase auxiliary forward propulsion will be added in the plan to extend the forward speeds above 200 knots.

The rotor systems research aircraft (RSRA) is a unique rotary wing aircraft that is conceived as being a flying wind tunnel and flying test bed for new rotor concepts. (18) Designed to accommodate a variety of new rotors, the transmission and rotor mounting utilizes an active vibration isilation system. Such a system will allow the use of rotors having greatly different characteristics. Instrumentation includes provisions to measure rotor forces and rotor moments as well as propulsive force and wing lift. The aircraft will be used to verify data on new rotor concepts taken in full scale wind tunnels, data taken with other test aircraft, as well as serving in its primary function as the test bed for new rotor concepts.

At another level remotely piloted vehicles (RPV) in the form of the tethered Kiebitz and the small Wisp helicopter appear to offer significant potential to military users. The Kiebitz is a tethered pressure jet helicopter supplied with fuel from the ground through a tether cable. (15) It is designed to support radar and other sensors at 300 meters above the ground for periods of time up to 24 hours. Flight testing of the Kiebitz is underway.

The Wisp is a very small helicopter, a mini RPV, 1.5 meters in diameter with an all up weight of 30 Kg. (23) This is an exploratory vehicle to demonstrate the feasibility of small rotary wing mini-RPV aircraft. The mission equipment is a small black and white TV camera with a video link back to the ground station. The entire unit is designed to fit into a standard military truck. The initial testing of the Wisp has revealed that the aircraft can be flown and controlled remotely.

Although not explicitly discussed during the formal presentation RPV technology may have an important impact on the research and development of helicopters. Based upon the success to date of the fixed wing RPV's such as the U.S. Army Aquila, the radio controlled model helicopters, the Kiebitz and the Wisp, it is possible to forecast that the RPV approach may be used to explore new rotary wing concepts and configurations. RPV's may serve as an integral part of the research and development cycle of manned as well as unmanned rotary wing vehicles. Such a pattern is already evident in the F-15 RPV research vehicle testing done by NASA Flight Research Center. A similar use of RPV rotary wing experimental aircraft could allow experimentation with new concepts at markedly reduced cost and risk. A problem of scaling will exist which is similar to that found with wind tunnel models, yet the apparent benefits may be great enough to warrant consideration of the use of RPV's in an R and D role.

2.4 Wind Tunnel and Flight Research

A very wide range of research is being undertaken in various wind tunnels and in flight. Extensive wind tunnel capability exists in several countries including the United States, France, and Germany. A decade ago little wind tunnel time was made available for rotary wing testing anywhere in the NATO countries. Many wind tunnels were reluctant to accept helicopters, and the helicopter industry did not have a historical pattern of using wing tunnels in the development of either rotors or new aircraft. In the past decade existing tunnels have been made available for helicopter research and new tunnels specifically designed for helicopter and VTOL testing have been put into use. Plans are underway to modify the NASA Ames 40 by 80 foot tunnel to make it more suitable for testing advanced rotary wing concepts at higher speeds. Large amounts of tunnel time are now committed to fundamental aerodynamic research on such specialized concerns as the nature of non-steady stall of helicopter rotors. (22) Basic wind tunnel work has led to an increased understanding of airfoil stall, flow characteristics at the tips of rotor blades at high Mach number, as well as to the development of improved airfoil sections.

The tunnels have also been used extensively in the study of noise phenomena. The influence of rotor blade passage near a trailed concentrated vortex has been investigated. An example of this is the work in the S3 Chalais-Meudon wind tunnel which indicated a loss of lift of the intercepting blade coupled with a large increase in drag. (22) Several wind tunnels now have the capability to provide six component balances within the helicopter model and are able to separate out main rotor forces and moments from those generated by the fuselage. Internal balances are also available to measure tail rotor contributions. (20,22)

The attitude towards wind tunnel testing has changed so completely that not only are the tunnel staffs actively seeking helicopter problems to study, but the helicopter producers are utilizing tunnels extensively in the development of new aircraft. The S-76 underwent extensive model testing in the UTRC tunnel and the full-scale rotor underwent testing in the NASA 40 by 80 prior to flight test. (13) In the cases of the XV-15 and the ABC extensive full-scale testing of rotor systems was accomplished prior to committing the rotor system concepts to final design for flight articles. (16,17) Both these aircraft are scheduled to return to the 40 by 80 tunnel for test as part of the overall evaluation and development of the aircraft.

More and more wind tunnel tests are being run to improve the external aerodynamics of rotary wing aircraft. The results of this can be seen in the clean configurations of the Aerospatial AS-350, the Bell 222, the Sikorsky S-76, and the Bell XV-15. Clean aircraft offer greater speed and productivity. With these higher flight speeds greater attention must be paid not only to aerodynamic drag but to the aerodynamic features that influence stability and handling qualities. It may be anticipated that military aircraft will also require improved aerodynamic cleanness. Potential air-to-air combat, the desire for self-deployability and reduced reaction time, would require increased flight speed. If such trends do occur then increased wind tunnel testing of military aircraft will follow.

A very effective means of simulating aircraft and helicopter flight characteristics has been achieved by the Canadian National Aeronautical Establishment. (19) A Bell model 205 has been modified for use as an inflight simulator. Two control modes are possible, model following and control augmentation and feedback. Two of the most recent Sikorsky developed

helicopters, including the RSRA, have been simulated with good results.

While assessing the status of the helicopter development today, a challenging evaluation was made that one cannot expect the large gains in helicopter performance made in the past decade to be continued at the same rate. (21) The opinion was expressed that attempts to improve aerodynamics and rotor performance might move into an area of diminishing returns. It should be noted, however, that one has to view this thought in context of the new, clean, optimized commercial helicopters rather than the military aircraft where design priorities have in the past not put a premium on productivity nor reaction time. It was recommended that intensive research and development be now focused on areas which impact the cost of ownership and operation of helicopters. Improved design to reduce parts count, reduce maintenance man-hours, and provide for on-condition replacement was emphasized. (5,12,13,14,21)

Specific concern was expressed over the noise of helicopters. It was pointed out that the primary tool presently available to reduce external noise was a reduction in tip speed, and that approach could lead to a weight penalty of approximately 10% of the payload for each 3 DB reduced. Recent studies indicate that helicopter noise is far more sensitive to rotor speed that previously considered, and it may be possible to further control rotor noise by continued research. (21)

2.5 Common Ground for Military and Civil Cooperation in the Development of Rotary Wing Aircraft

Central to the theme of this FMP meeting on rotorcraft design were the papers and discussions held relative to the civil and military interface. In the area of smaller helicopters in the range of 4000 to 10,000 pounds financial capability of the manufacturers is adequate to undertake development of civil helicopters. (24) Industry can foresee sufficient commercial markets to justify the cost of development and production. It remains desirable, however, for companies to develop small helicopters in concert with the military. In a purely civil design the lack of precise needs and goals tends to contribute to an uncertainty of how to proceed with a new aircraft. This uncertainty couples with the difficult decision needed to commit a large amount of funds to cover non-recurring costs which will be lost if the program is unsuccessful. The difficulty is compounded by the recognition of the long time required for payback through increased selling price as compared to a military funded program where non-recurring costs are covered or shared.

Even in the absence of military sponsorship, significant gains in technology are incorporated in the newer commercial helicopters such as the AS-350, BO-105, 222, and S-76. Significant advances such as flexural rotor heads, fiberglas blades, and widespread use of advanced composites may be found. (11,12,13,14) Such commercial aircraft may also be adapted for use in a variety of military missions. By so doing, the military could get direct cost benefits. The unit price could be lower because of the larger production base and the sharing of costs. When the military does accept modified civil aircraft for military use, it implies an acceptance of civil standards and a potential lack of special military features. (5,10,11) In spite of the potential benefits, it became apparent that the direct application of civil helicopters to military use and military helicopters to civil use would be primarily limited to small helicopters, such as military trainers, small gun ships, or scout aircraft.

It was the concensus that military features such as crashworthiness and survivability must be designed and built into the helicopter from its inception. A typical weight penalty for crashworthiness would be of the order of 7% of the empty weight of the aircraft. A requirement for air transportability must be considered in the preliminary design stage of the aircraft. Though civil certifying agencies such as the FAA may move toward added crashworthy features to enhance safety, it is doubtful that they will require as extensive provisions as do the military. The redundancy and the shielding put in to withstand battle damage has no counterpart in civil aviation.

The cost and complexity of certifying helicopters for civil use is a major concern even when the aircraft is a well proven military aircraft. The civil certifying organizations and each has totally different goals and requirements. This makes the task of certifying a helicopter for wide use extremely difficult.

In the case of military qualifications, even the separate military services of a given nation, may disagree greatly. Where one service asks for survivability in combat, the other service requests shipboard compatibility. One asks for long duration flight and the other asks for hot-day, high-altitude climb capability. When civil certification is then considered, the differences may be even greater. The military qualification groups seek to insure adequate total mission performance whereas the civil agencies seek primarily to certify a minimum level of safety leaving the mission performance in the hands of the aircraft user and the producer. If consideration is also given to selling the helicopter in many nations, each with its certifying agencies, the complexity and cost to the manufacturer is compounded greatly.

Since the qualifying agencies seldom coordinate these requirements, it often happens that test times for dynamic components may vary by no more than 20% among agencies, yet completely separate qualification tests may have to be run. Each change to a proven aircraft such as the CH-47 or CH-53 may be relatively small, yet the total costs to qualify the aircraft can become quite large. It was estimated that to take the CH-47 through civil qualification would cost over $10,000,000 although the aircraft has over 1.5 million flight hours of quite successful service. (25) If it is desired to certify the aircraft in other countries, added development and test may also be needed.

The impact of highly specialized military requirements can be seen in a comparison of two

new helicopters. The civil Sikorsky S-76 can carry 12 passengers plus 2 crewmen at a gross weight of 9700#. (13) The military UH-60A made by the same manufacturer accomplishes that at a gross weight of 16,800#. (5) This larger gross weight of the military aircraft is the direct result of different mission requirements. The UH-60A is designed to hover on a hot day at altitude, and is designed for a combat environment. The S-76 is not. In the case of the Vertol UH-61A, if a similarly sized helicopter had been built for purely civil use it could have carried 30 passengers instead of the 11 passengers the military version carries, but the civil version could not have met essential military requirements. (25)

These military requirements have arisen from the lessons learned in combat. Crashworthiness and survivability criteria are the result of service experience. MIL-STD-1290 was written in response to well documented crash data. Since the incorporation of crashworthy fuel systems, no cases of thermal injuries or deaths have occurred. This record must be contrasted with about 200 recorded cases prior to installation of these systems. (25) The specifications of military agencies must and do reflect their special needs and experience.

2.6 Considerations on the Coordination of Military and Civil Requirements and Specifications

During a panel session delegates were challenged to consider many possible aspects of military and civil certification procedures. It was generally agreed that the cost and complexity of certifying aircraft to civil standards was increasing. It was also agreed that the capabilities of the military aircraft are diverging from those of civil aircraft. Hence typical questions addressed were "Why should the costs be so high to certify a proven aircraft"? "Why is it so difficult to achieve joint certification to meet both civil and military qualification standards"?

The manufacturers pointed out that it may be necessary to certify a civil helicopter to different qualification standards for each military and civil agency in each country where they are to be used. Though the aircraft may be essentially identical, yet the certification process may have to be repeated to meet a second set of standards. If a change is made to a helicopter, re-certification must be accomplished for all nations where the helicopter is used.

The manufacturers felt that a move towards some type of international certification standards would be useful and that a move towards commonality should initially focus on common standards and qualification procedures for selected technical areas and subsystems. As an example, a component test may require 150 hours in one country and 200 hours in another. Manufacturers must face the problem of trying to meet both tests with one run since inspection at the lower time voids the higher time test. They may feel forced to do both tests, and face considerable added expense.

The representative of the United States Army also spoke in support of the view that commonality between civil and military helicopters perhaps could best be initiated by qualification of subsystems and components. Since a very large portion of the cost lies in the lift, drive and engine system, could not an attempt be made to achieve commonality on these critical and costly components?

He also suggested that closer coordination of certification requirements and procedures should be undertaken both within the United States and within NATO. The United States military services should take the first step by developing common military standards and specifications for helicopters to the maximum extent possible within differing missions. He also questioned whether it might not be possible for the FAA, a) to place greater emphasis on the quality of the product, b) to place emphasis on raising the level of airworthiness above the minimum level that insures safety, c) to seek ways by which joint qualification test programs could be achieved.

The FAA representatives responded to the concerns about the level of standards by stating that by law the intent of the ciril air regulations is to insure that a minimum level of safety is met. The manufacturers and the air carriers have the duty to provide the highest safety possible. In reply to the U.S. Army representative, the FAA believes the minimum standards of safety are really quite high and that a reasonable balance between safety and cost must be realized. The FAA representatives discussed existing bilateral agreements used to certify aircraft between countries. Under these agreements, the FAA asks other countries to indicate the differences in qualification requirements. The aircraft company must then certify that the aircraft meets its home nation specifications plus the added requirements to meet FAA needs.

The delegate from France indicated that joint programs between nations could work well and cited the closely coordinated programs in helicopter development between the United Kingdom and France. Each partner in such an agreement has his own input into the development although the ultimate use to which each country puts the helicopter is not the same. This type of collaboration has been extended to an agreement on the overall characteristics of a light attack helicopter. Efforts are also underway to define the characteristics of a European UTTAS.

It was also pointed out that one of the obstacles to achieving standardization and cooperative ventures among companies and countries is the different time phasing resulting from different priorities in the various NATO countries. Thus, while one NATO member may see a need for a utility helicopter clearly, another may opt for an attack helicopter. If such timing differences cannot be resolved such high costs may result that new developments might not be initiated. Thus the joint effort made to develop the characteristics of the LAH and European UTTAS is a very positive step.

The delegates were reminded of how difficult it is to achieve wide commonality in specifications. Serious doubt was expressed by representatives of the U.S. Navy concerning the ability to resolve technical differences between military services in specifications. Significant differences do exist in the missions and operational characteristics between Army and Navy helicopters and the specifications reflect this. Attempts made to bring in the FAA would only compound the difficulty. When the time comes for actual qualification of an aircraft each agency will want to conduct tests to demonstrate compliance with the requirements it sees as critical. No agency will want to give up this ultimate acceptance testing which verifies the quality and safety of the item they will use. (25)

3.0 Evaluation and Recommendations

3.1 Overall Comment Relative to Military-Civil Helicopter Development and Use.

Military and civil helicopters in several areas are drifting apart in their design features and mission capabilities. This lack of commonality could lead to increased costs and lower production runs. This disparity appears to be more critical in larger size helicopters than in the smaller helicopters.

Recommendation:

Seek out and foster ways to maximize common mission and design features through early planning, international coordination of requirements, certification standards, and qualification testing.

3.2 Specific Comments Relative to Military-Civil Development and Use.

3.2.1 Increasing incompatibility of new military helicopters such as the United States UTTAS for use as civil aircraft. Large costs are involved to make entirely new configurations suitable for civil use.

Recommendation:

Since it will be difficult and expensive to reconfigure the military aircraft to meet the civil need, an alternative of trying to achieve subsystem commonality wherever possible should be considered. Aim to develop and qualify such subsystems and components to joint specifications.

3.2.2 A lack of commonality exists with regard to military requirements. This lack of coordination of mission and mission equipment exists.

(a) within a country among the military services, and

(b) between countries within NATO.

Recommendation:

Attempt to correlate requirements at an early stage. Attempt to develop core dynamic components about which variations can be made similar to the "core engine" concept. Attempt to define aircraft which will do basic required tasks, and not let one specific task drive the entire configuration out of proportion to its importance.

3.2.3 A continuing requirement exists for a heavy lift capability in the military sector.

Recommendation:

(a) Coordinate requirements early,

- between military and civil

- between nations

(b) Seek joint financing between countries as with the A 300.

3.2.4 A need exists for a civil helicopter in the CH-53 or CH-47 class. The costs of certification and modification of such aircraft for civil use are almost prohibitively high. Since production quantities are anticipated to be low, production costs may be high.

Recommendation:

(a) Seek commonality of civil airworthiness certification procedure.

(b) Seek multi-nation coordination of civil needs.

(c) Seek alternate uses for the aircraft to increase production base.

(d) Seek multi-nation coordination of military-civil medium cargo helicopters.

(e) Seek multi-nation coordination/development of military-civil cargo-transport with "quick change" conversions similar to what is available in fixed wing transports.

3.2.5 The lack of commonality of civil airworthiness specifications and qualification procedures among nations limits the feasibility of certification because of the increased costs.

Recommendation:

(a) Seek to encourage civil authorities to coordinate their specifications and procedures.

(b) Encourage development of a common core specification and qualification procedure from which variations could be made for specific applications.

3.2.6 There was concern on the part of civil operators that the military developing agencies may allow higher aircraft vibration levels and noise levels by relaxing the stated low levels.

Recommendation:

Conduct a study to determine what the acceptable levels should be for both civil and military helicopters. Attempt to establish realistic ceilings on the levels. Encourage development of common requirements.

3.2.7 Crashworthiness provisions in new military aircraft are very costly, increase empty weight by 7-10% and may not be as essential in civil aircraft.

Recommendation:

(a) Encourage a study on the effects of the crashworthiness provisions on procurement and operating costs of civil aircraft.

(b) Determine what portion of crashworthiness provisions may be useful to civil aircraft and what the impact on weight and cost would be.

(c) Study the trade-off of getting some (adequate) protection versus "full" protection for military aircraft and the corresponding impact on civil aircraft.

3.2.8 The cost of research and development of new helicopters and rotary-wing concepts is high and is increasing in the face of inflation and declining governmental expenditures. This situation will lead to the decrease in the ability to produce the improved aircraft needed in the future.

Recommendation: Encourage

(a) Joint military-civil research and development on the more expensive demonstrator concepts such as has been done in the United States with the XV-15 and the Rotor Systems Research Aircraft.

(b) Joint acquisition and use of research facilities such as wind tunnels with member nations.

(c) Cooperative use of research facilities between countries within NATO.

(d) Joint research and development of new helicopters such as was done with the Puma and the Lynx. Extend this concept to other NATO countries.

(e) Joint research and development programs to investigate the fundamentals of rotary wing aircraft.

(f) Joint programs on subsystem development.

3.2.9 It has been difficult to get the groups responsible for the development, certification and procurement together and working in concert. This difficulty exists for military agencies in a given country and for the military and civil agencies within a country. It is expected it will be even more difficult to get the same groups working across national boundaries with the similar groups in other countries.

Recommendation:

(a) Foster specific working groups with well defined and limited objectives and deadlines.

(b) Encourage the writing of central core specifications covering missions, qualification standards, and qualification procedures.

3.2.10 Icing of helicopters was considered to be a problem for both civil and military operations.

Recommendation:

(a) Continue research and development on ice protection systems.

(b) Determine the level of protection needed.

(c) Determine if common features of the problem exist between civil and military.

(d) Attempt to develop common joint specifications, military and civil, and between the countries of NATO.

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5.0 Appendix I

Icing

Sufficient comments were made relative to icing that the material is summarized here as an appendix to the TER.

The meeting revealed a mixed viewpoint as to the importance of icing in operational use of helicopters. Helicopters are routinely flown by BEA in light icing conditions in support of off-shore drilling rigs in the North Sea. (7) A 20,000 pound helicopter may acquire up to 500 pounds of ice yet the pilots report no significant difficulty in flight. Accretion on the controls and particularly the pitot head can be troublesome. (7) In these airline type operations, BEA has not been able to photograph ice on the blades after shutdown even though the blades are not deiced.

Operation of helicopters by KLM in support of oil drilling in the North Sea off the coast of the Netherlands has been primarily guided by the principle of avoiding any icing conditions. (9) Hence, no experience with actual icing was reported.

In the case of rescue operations by the Norwegian Air Force in far northern latitudes, helicopters are routinely operated under all weather conditions. (8) Severe icing conditions are avoided and if encountered while flying over water, the pilots drop down to fly just over the ocean where ice accretion is not a problem. When flying over land and mountainous terrain, they must alter the flight plan to avoid the ice. Need was expressed for a helicopter that could fly on a straight path at 10,000 feet directly through icing conditions.

In the case of military operations, explicit detail as to the icing conditions encountered or planned for was absent. (1,2,4,5,6) The U.S. Army stated that it does have a requirement for an operational de-icing system and that the Army must be able to fight and fly in all weather including icing. (1) Though the necessity to fly into icing conditions was recognized, there are no fully qualified blade de-icing systems on operational U.S. Army helicopters. In future Navel operations, the helicopters will have to fly above 5,000 feet for long duration. (4,6) Hence the probability of encountering icing conditions is expected to be much greater. It was considered essential that ice accretion near engine inlets and ice injection by the engines be investigated thoroughly in suitable facilities. (21,13) Canadian helicopters were operated from small naval vessels in a variety of weather conditions but flight in icing conditions was avoided. Operational experience with icing was not acquired. (3)

If one now examines all the discussions about icing, it is apparent that general concern exists but no clear pattern emerges. Research efforts continue (2,4,5,27) aimed at providing de-icing capability of rotor blades. Commercial operations continue without specific active protection and military aircraft in general do not carry a full suit of ice protection. Concern exists over whether the ice protection system on military helicopters may indeed pose a greater hazard than the ice since the radar cross section may be increased significantly. (1)

What appears to be necessary is a careful evaluation of the icing actually encountered by helicopters and its effect on performance, engine, control, and vibration. It is expected that military agencies such as the U.S. Army Aviation R&D Command have conducted such surveys in conjunction with their rotor de-icing development programs. If so, such surveys should be made available to all members. Based upon such surveys, some definite criteria for icing should be set up defining the levels of protection needed to meet various icing conditions.

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14. Abstract

This report presents a review and evaluation of the Flight Mechanics Panel Symposium on Rotorcraft Design. It is apparent that the levels of technology of both military and civil helicopters now entering service are very high. It is also evident that the highly specialized requirements of the military aircraft have caused the military helicopters to be less useful for direct application to civil markets. Of prime concern is the inability to produce derivatives of the large military transports for use as commercial airline helicopters. It was clear that the reason for this was the complex, costly civil certification required combined with a limited market as seen by the manufacturers.

Technical Evaluation of the AGARD Flight Mechanics Panel Symposium held at Moffett Field, California, USA 16–19 May, 1977. The proceedings are published as AGARD Conference Proceedings No.233.

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